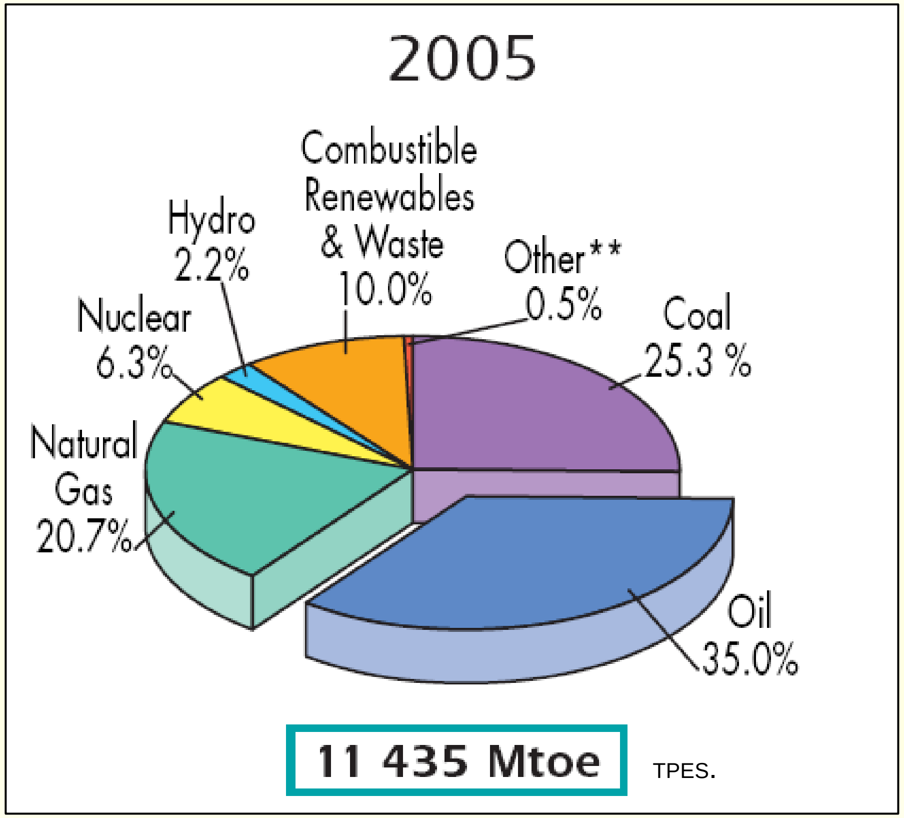
BIOFUELS: WHY AND HOW ?

Dr. Gilles Vaïtilingom

BIOFUELS FUNDAMENTALS

- **Key World Energy Stats**

Total Primary Energy Supply
In the World - 2005

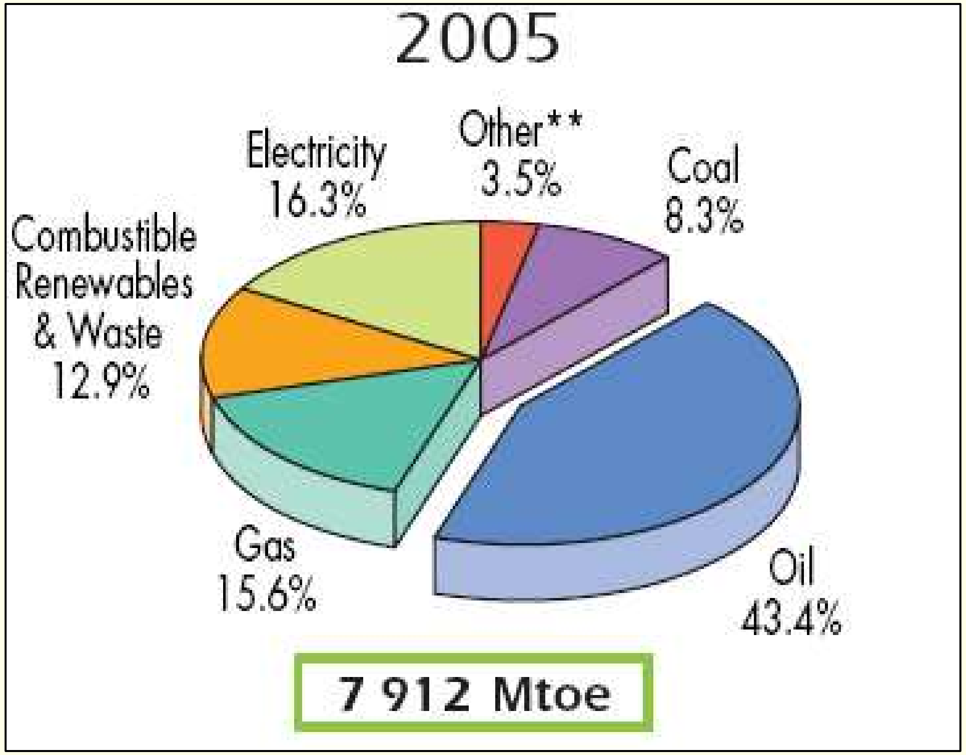


** : wind, solar, geothermal, ...

✌: 81 % from Fossil Resources

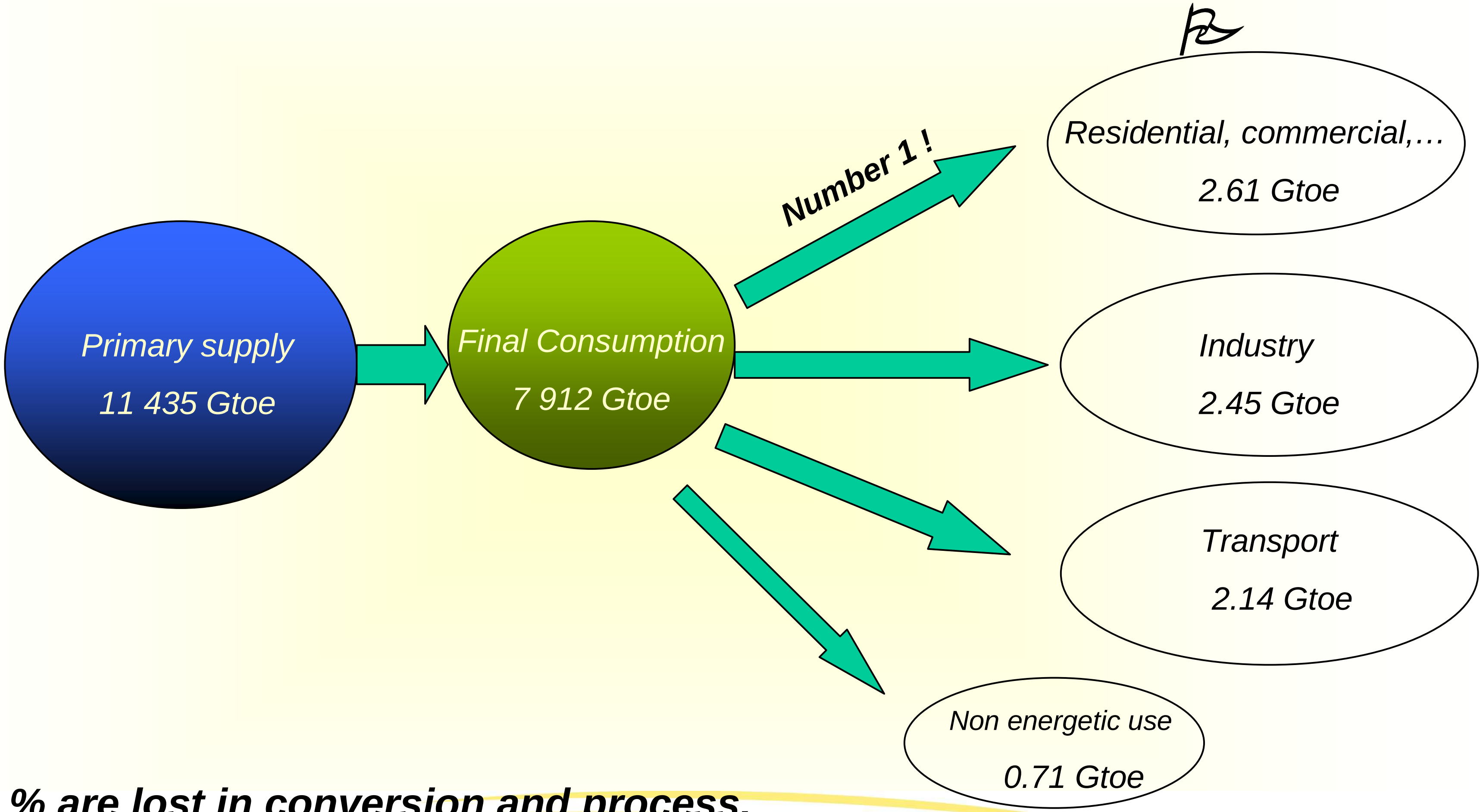
Source : IEA, 2007.

Total Final Consumption In the World - 2005



Source : IEA, 2007.

Total Final Consumption
In the World - 2005



: 31 % are lost in conversion and process.

Source : IEA, 2007.

INTEREST OF BIOFUELS

Two points :

- Humanity is producing and consuming such quantity of energy only since the industrial era,
- There are 3 primary energy forms:
  - 1. Fossil (81 % of primary supply)
  - 2. Nuclear (6.3 % of primary supply)
  - 3. Renewable** (12.7 % of primary supply)

** : biomass, hydro, wind, solar, geothermal, ...

INTEREST OF BIOFUELS

- 81 % of the energy consumed worldwide come from fossil resources
- during the 20th century we have consumed more than 50 % of exploitable world reserves

INTEREST OF BIOFUELS

- Each second, nature is (re) generating 100 liters of crude oil, but we are consuming 150 m3
- If people were consuming as US citizens do exploitable oil reserves would last only 10 years
- there are 10 millions cars in China, and 100 millions in 10 years

BIOFUELS INTEREST

Before 2050,

it is a duty and a necessity to look for solutions by all means:

- to improve our energetic efficiency
- to stop wasting energy
- to develop renewable resources

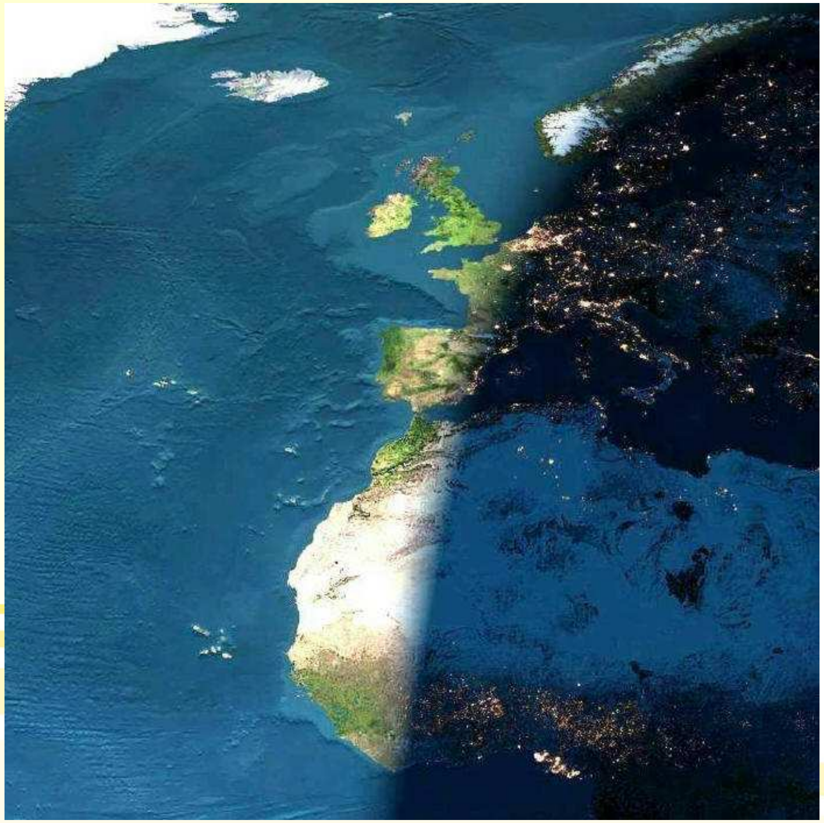
Source : R. Olivès

Univ. Perpignan

PROMES-CNRS

We all need Energy

- food
- dress
- heating
- cooling
- health
- entertainment
- work
- …



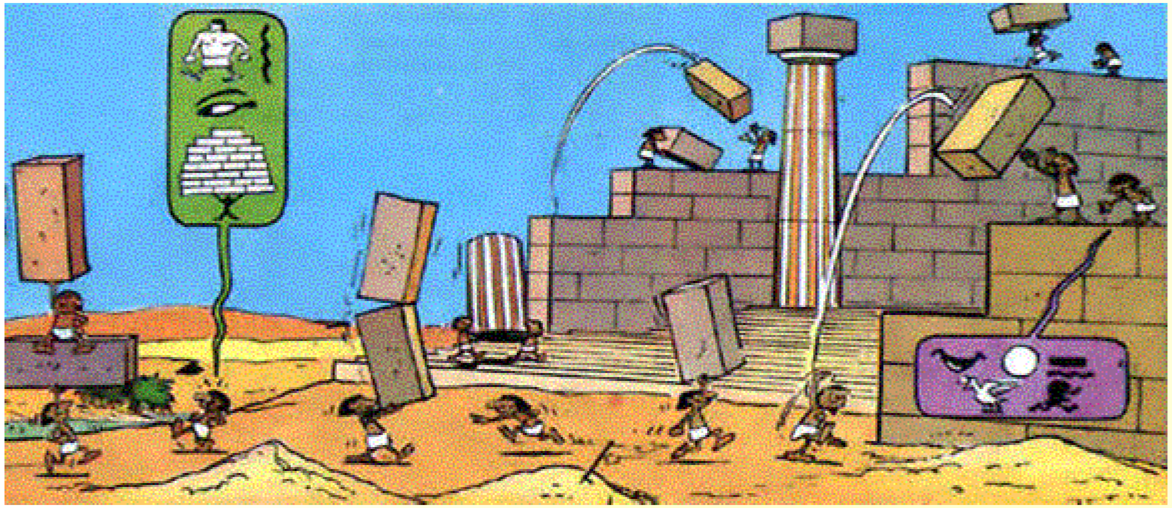
Source : R. Olivès
Univ. Perpignan
PROMES-CNRS

We are Energy eaters

Energy Resource → Needs

Source : R. Olivès
Univ. Perpignan
PROMES-CNRS

We need more and more

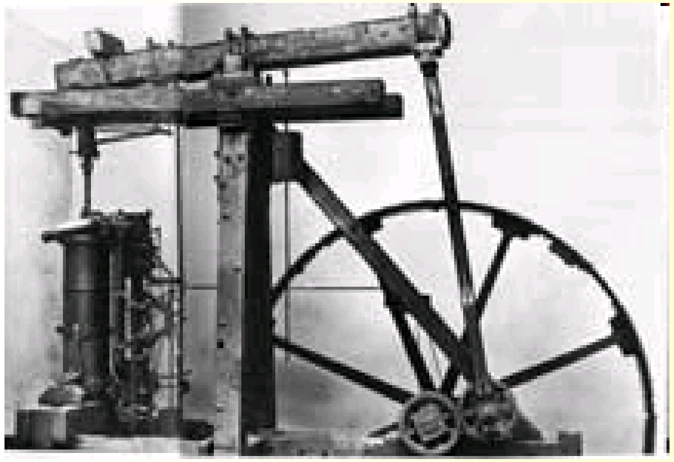


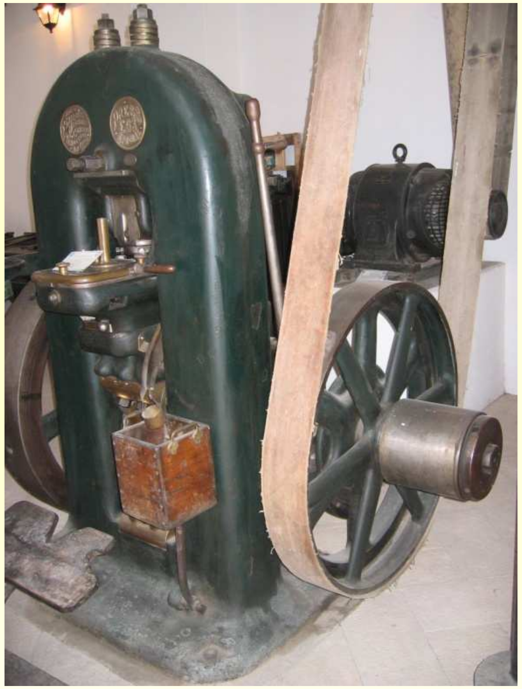
Source : R. Olivès

Univ. Perpignan

PROMES-CNRS

More and more Power





Source : R. Olivès
Univ. Perpignan
PROMES-CNRS

MORE AND MORE POWER

Annual Average Growing Rate of Energy Consumption

Oil: + 1.3 %

Coal: + 3 %

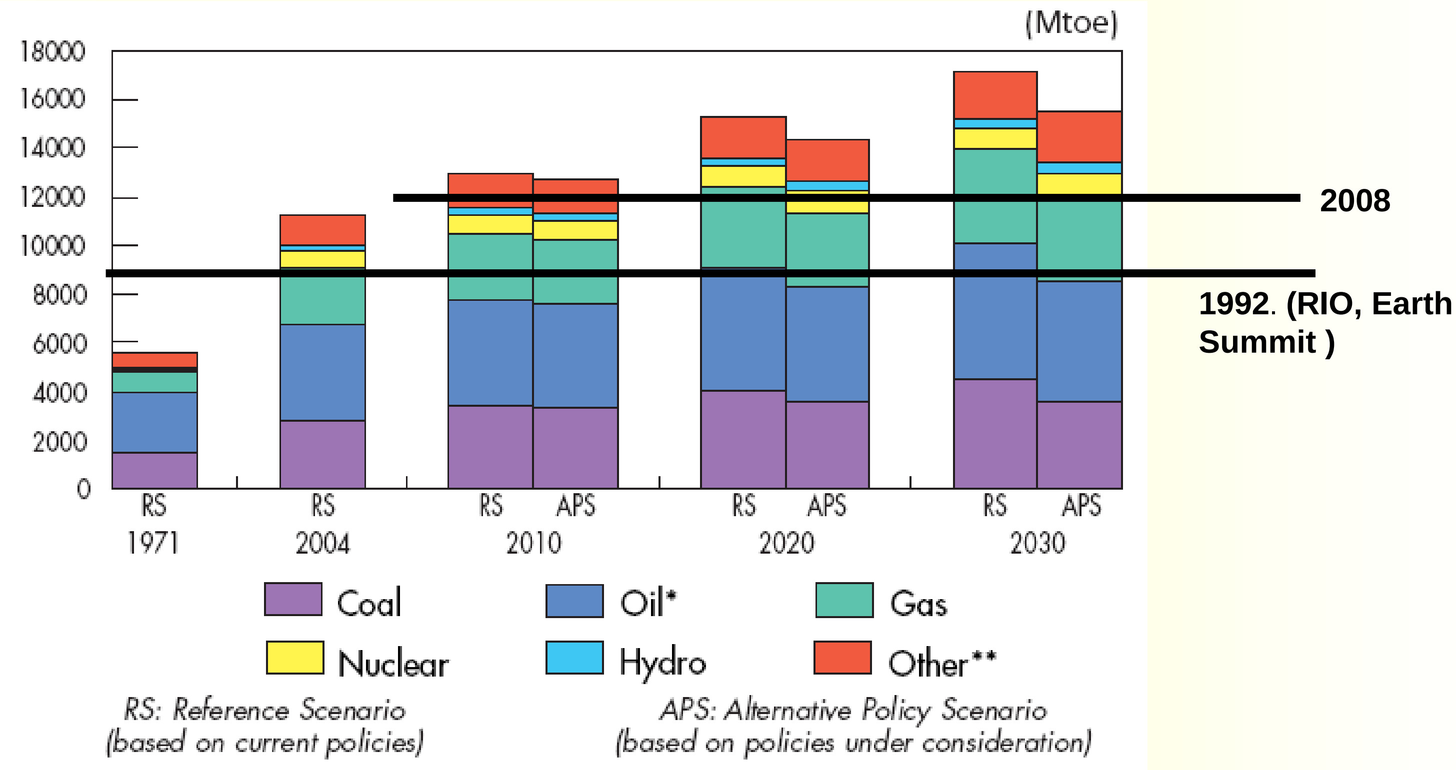
Natural Gas: + 2 %

Electricity : + 3.2 %

Total Primary Energy Supply: + 50 % in 2030, + 100 % in 2050
TPES

Source : IEA, 2007.

Outlook for World TPES in 2030



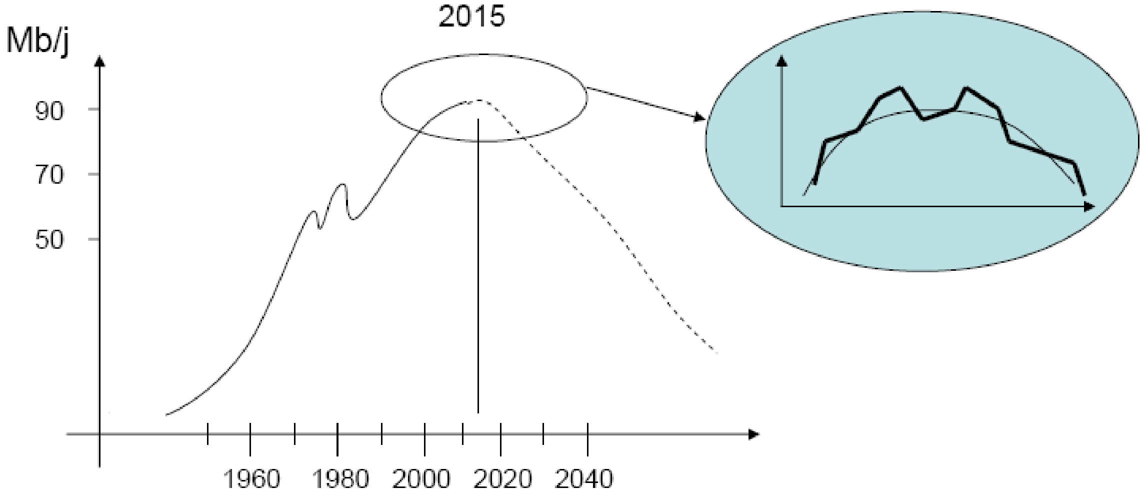
: In 2030, transports will consume 3900 Mtoe of oil, EQUIVALENT TO 2007 ENTIRE WORLD OIL PRODUCTION.

Source : IEA, 2007.

Peak Oil coming soon ?

La production de pétrole va bientôt entrer dans sa phase de déclin continu

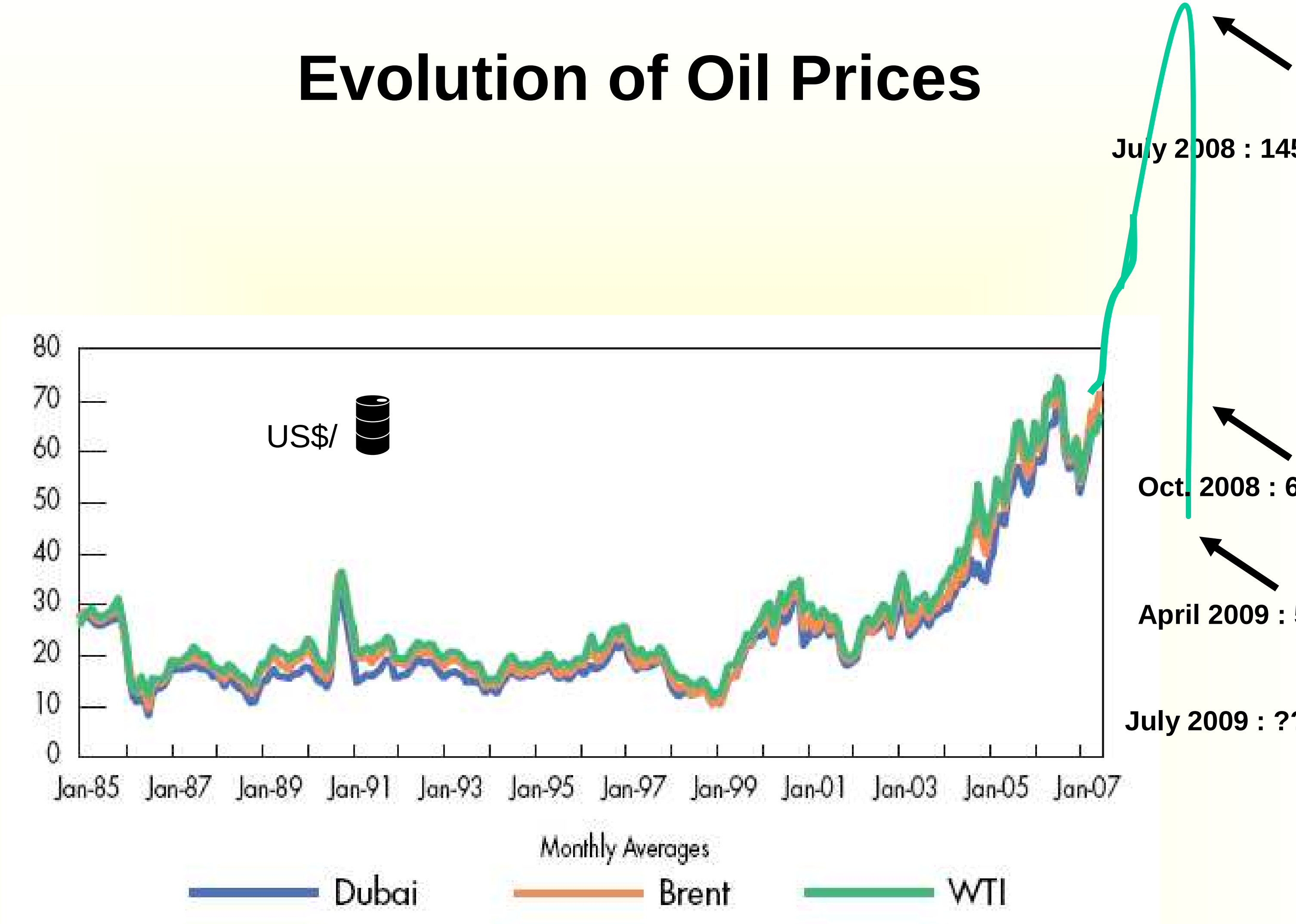
Pic de production : maximum de la production journalière de pétrole



Courbe de Hubbert appliquée à la production mondiale (Laherrère, 2004)

Source : R. OLIVES (PROMES).

Evolution of Oil Prices



July 2008 : 145 US$

Oct. 2008 : 65 US$

April 2009 : 50 US$

July 2009 : ??? US$

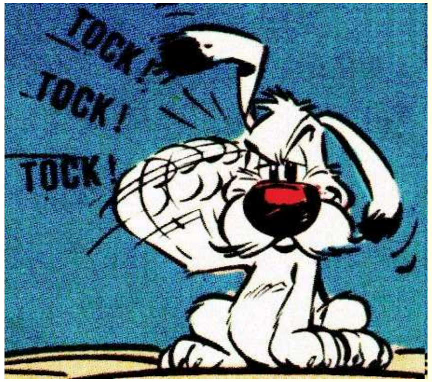
Source : IEA, 2007.

Source : R. Olivès

Univ. Perpignan

PROMES-CNRS

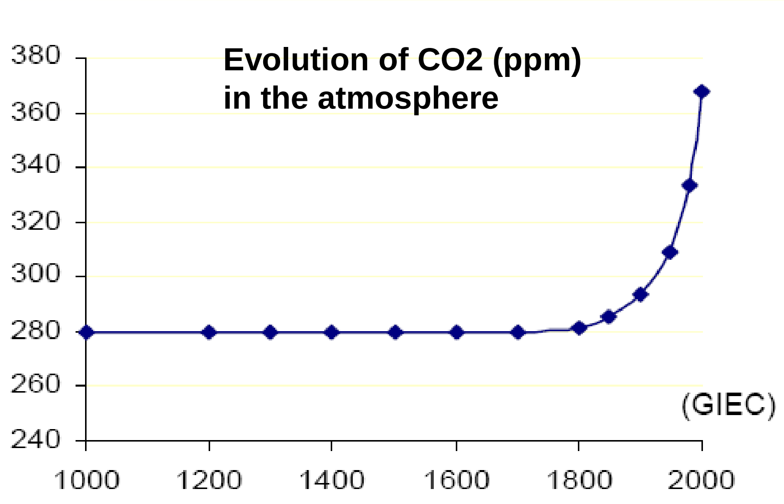
Availability : $\frac{\text{Reserves}}{\text{production}}$



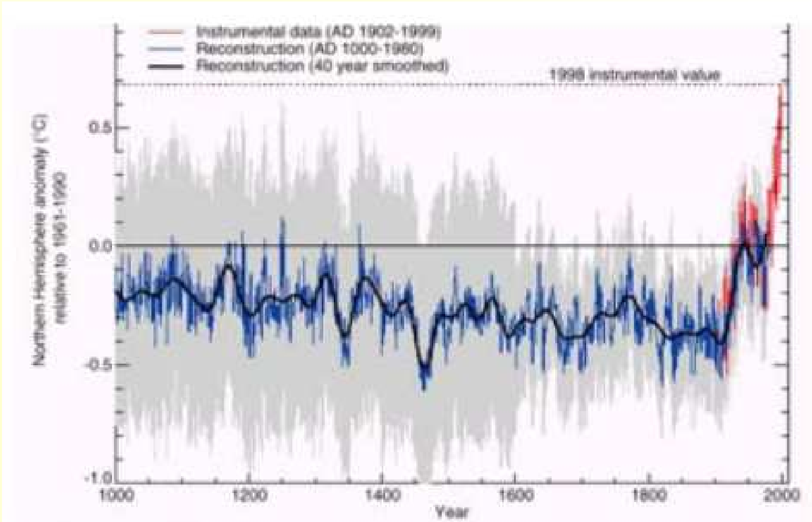
OIL	40 years
NAT. GAS	60 years
COAL	230 years
uranium	60 ans…
RENEWABLE	unlimited !!!

Source : R. OLIVES (PROMES).

Global Warming / GHG



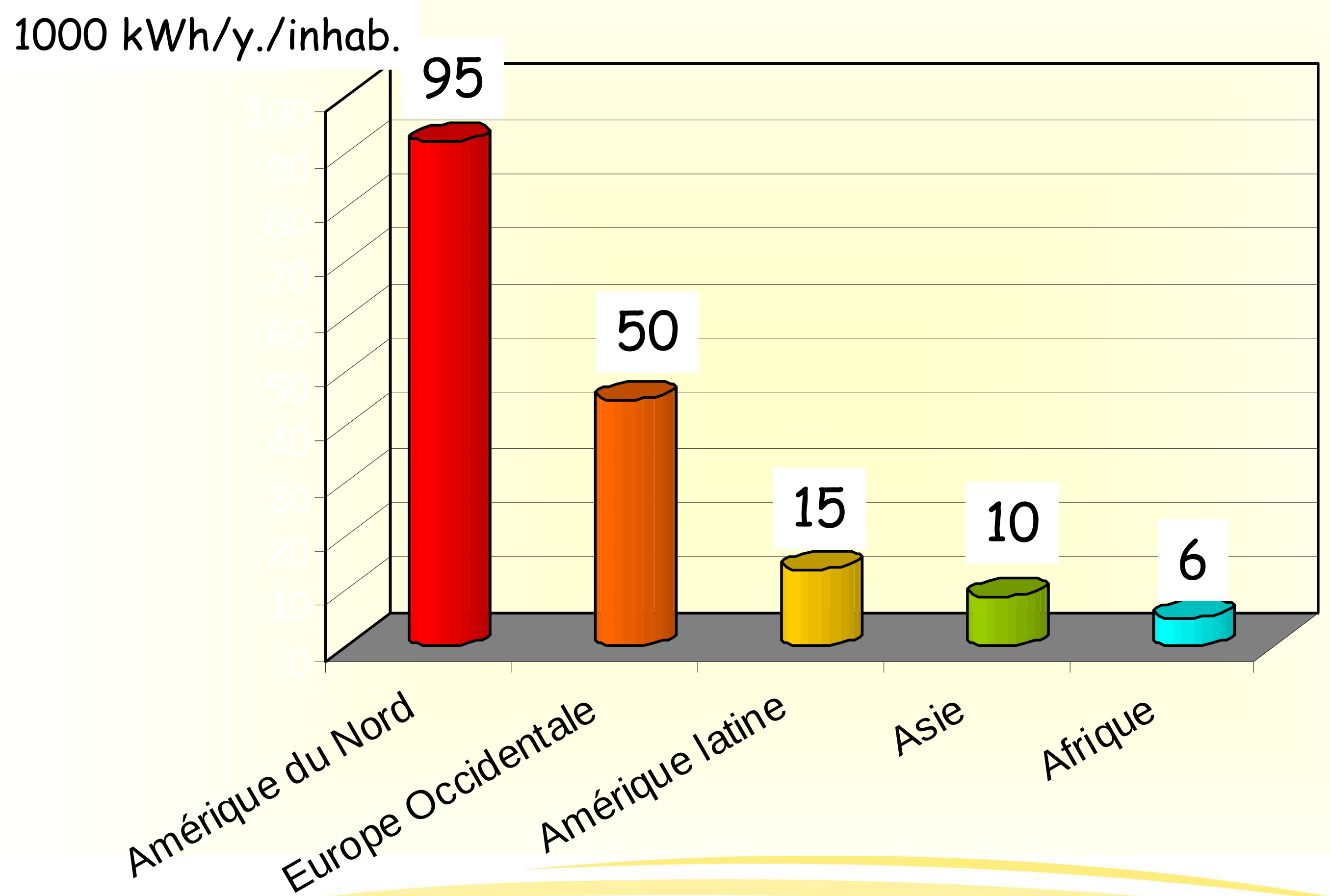
Evolution of temperature in the atmosphere (ref. 1961)



Source : R. OLIVES (PROMES).

Source : R. Olivès
Univ. Perpignan
PROMES-CNRS

Consumption of Energy per inhabitant per year



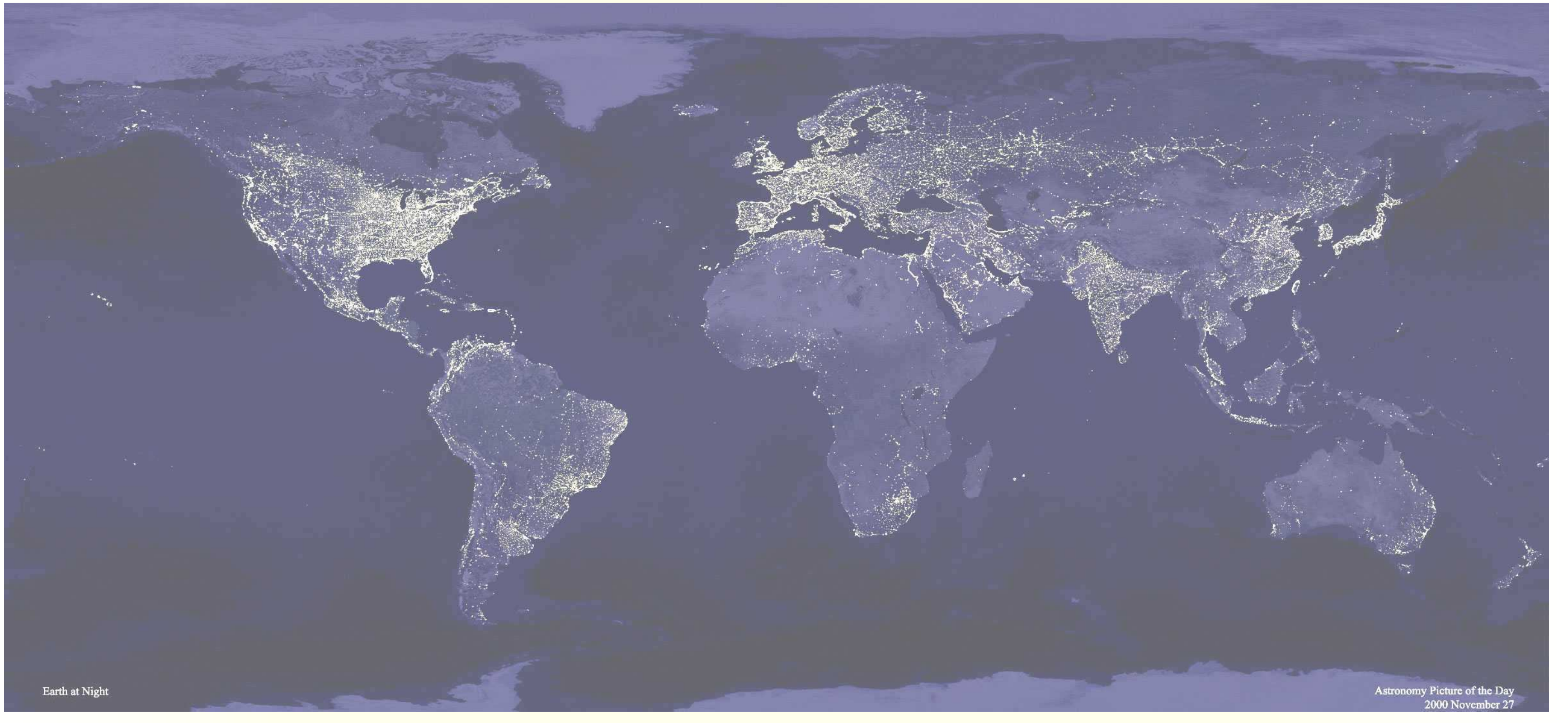
(Global Chance)

Source : R. Olivès

Univ. Perpignan

PROMES-CNRS

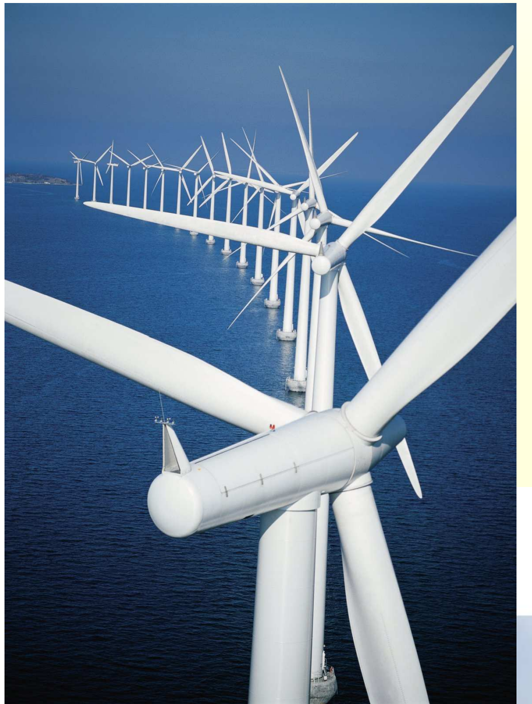
6 billions inhabitants but 2 billions without electricity



BIOFUELS FUNDAMENTALS

- **Why ?**

RENEWABLE ENERGIES ☞ not for liquid fuels substitution



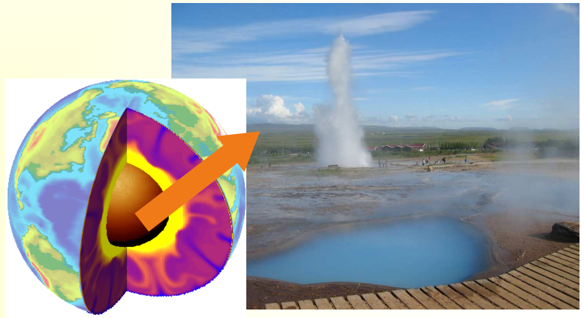
Biomass Gasification

Biogas

NEW AND RENEWABLE ENERGIES ☞ not for liquid fuels substitution

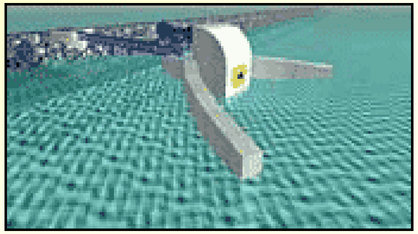
Solar Stirling engine

Geothermal

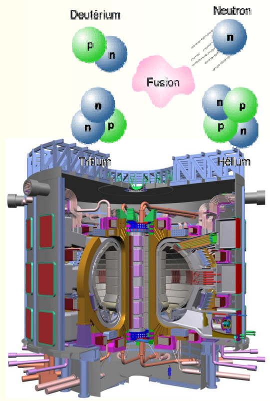


Pelamis (Ocean Power Delivery)

hydroliennes

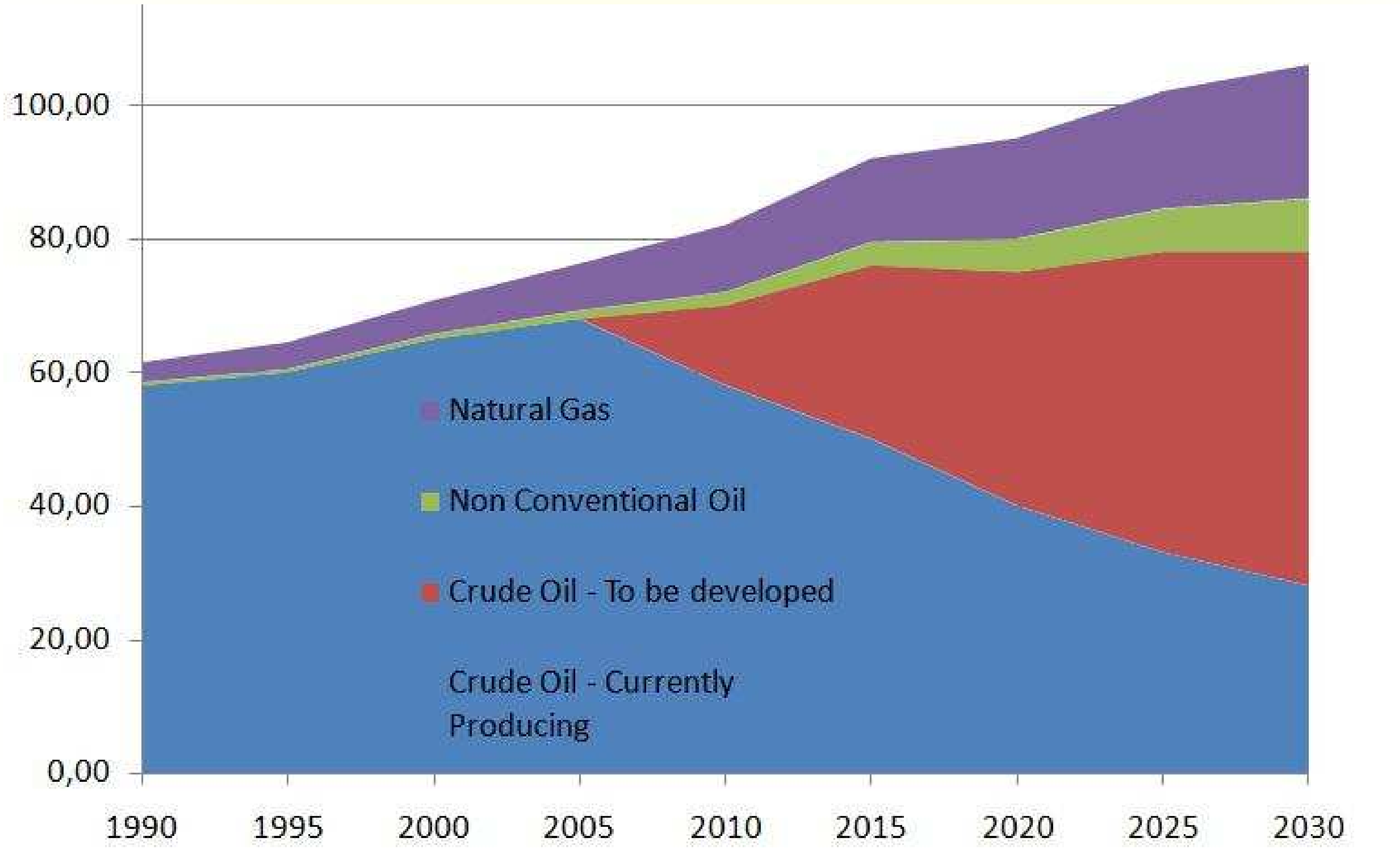


Energy from waves



Fusion : ITER

Updated Outlook for World in 2030



Source: IEA 2008

BIOFUELS FUNDAMENTALS

- **How ?**

BIOFUELS ????

BIOFUELS (1)

Fuels from Biomass **?**

- Firewood

  >10 % of world energy consumption (# hydro & nuclear)

  In many countries: 80 % of total energy sector

- Biogas

  Fermentation biodigestor ➔ CH_4

  Gasification of wood, agro-residues ➔ CO, H_2

BIOGAS

BIODIGESTOR – Natural gas for domestic purpose or small rural electrification (Wad Medani SUDAN)

BIOGAS

BIODIGESTOR – Natural gas for domestic purpose or small rural electrification (Amatuku – TUVALU)

BIOGAS

Rice husk Gasifier (Indonesia)

Electricity from crops residues

BIOFUELS (2)

BioFuels: Liquid Substitutes of Petroleum products

- **ALCOHOLS** Ethanol from sugar cane
  sugar beat
  mais (corn)

  Substitute of gasoline ☞ HIGH GRADE FUEL

  BRASIL, USA, EUROPE

- **Derivatives: ETBE** octane enhancer

  EUROPE

BIOFUELS (3)

Bio-Fuels: Liquid Substitutes of Petroleum products

- **VEGETABLE OILS** PALM, COPRA
COTTONSEED, PEANUT,
RAPESEED, SUNFLOWER, SOJA,...

Substitute of Diesel oil

EUROPE, South Pacific (New Caled., Fiji, Vanuatu,…), Africa, Latin America,…

- **Derivatives: Methyl and Ethyl Esters of Veg. Oils**

EUROPE (France: 4000 millions of liters rape&sunf / year)

BIOFUELS INTEREST

Biofuels are environmentaly friendly :

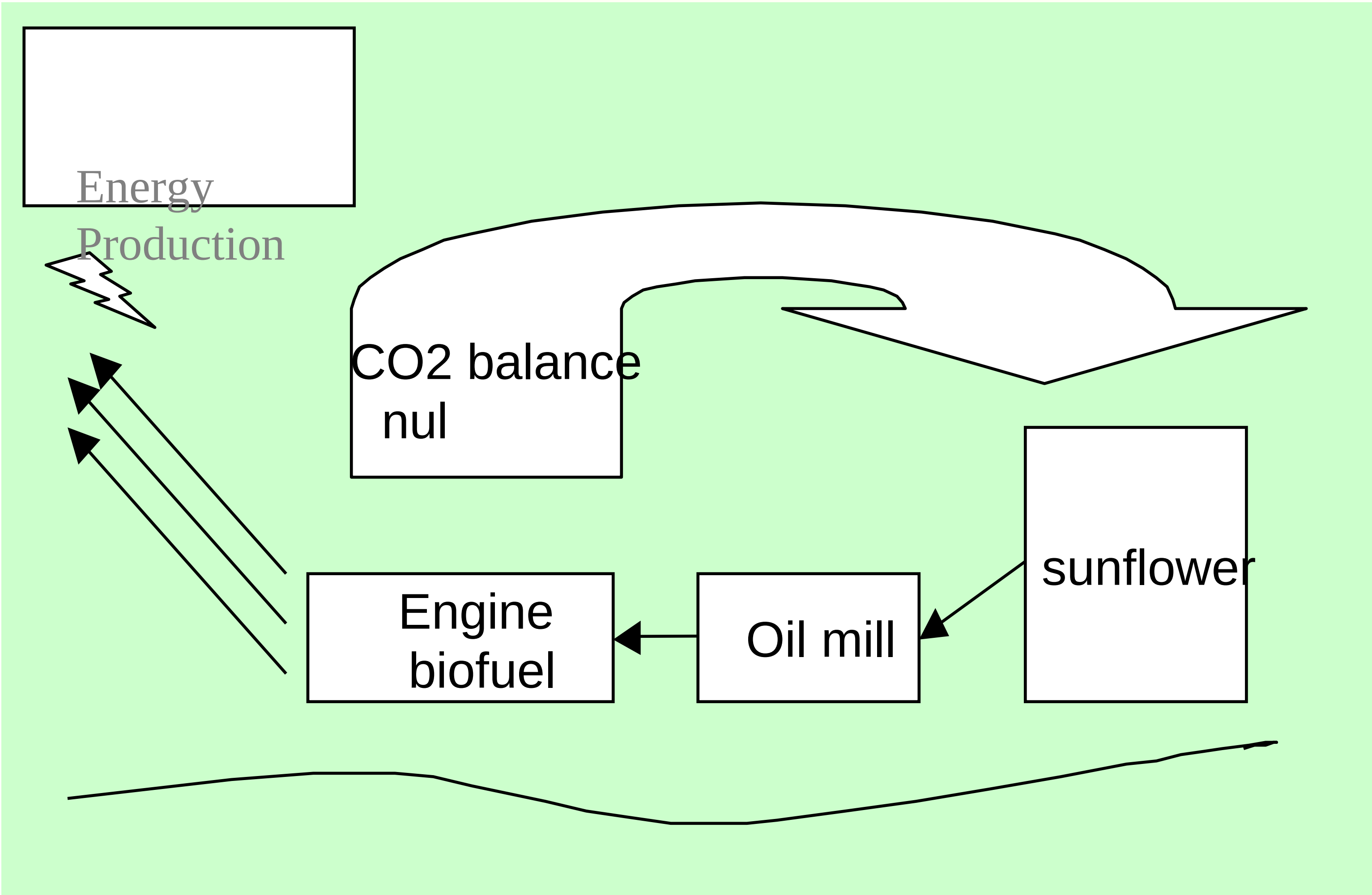
- **biofuels coming from agriculture don’t increase CO_2 rate in the atmosphere** **(TTW: tank to wheel)**

1000 litres of sunflower oil = 3.2 tonnes CO_2 saved

- **pollutants at the exhaust:**

- are respecting the legal limits in force prescribed for diesel and gasoline

- are benefiting of depolluting exhaust systems development


Energy
Production
CO2 balance
nul
sunflower
Engine
biofuel
Oil mill

BIOFUELS

Make power available

PRODUCTION

BIOFUELS FROM BIOMASS

- Ethanol
- methanol

Petrol engines

- acetone butanol (ABE)

Additive for blends of alcohol/gasoline

- vegetable oils natural or esterified

Diesel engines

BIOCHEMICAL CONVERSIONS
ethanol production (1)

Fermentation of organic, ligno-cellulosic or glucidic materials

→ Ethanol or similar products

Fermentescible ‘ juice ’ → Fermentation → Distillation rectification

BIOCHEMICAL CONVERSIONS ethanol production (2)

Fermentation of organic, Ligno-cellulosic and glucidic materials.

☞ saccharide materials (fruits,…)

Fermentescible ‘Juice’ → Fermentation → Distillation rectification

Diffusion, pression,…

Extraction of ‘ sugars’

ethanolic

Rectification

Dehydratation

BIOCHEMICAL CONVERSIONS ethanol production (3)

Fermentation of organic; Ligno-cellulosic and glucidic materials.

☞ saccharide materials (fruits,…)

Ethanol	Sugar Beat	Corn	Mais	Pota toes	cassa va	Sugar Cane	Topinam -bour
yield hl/tonne	0.905	3.9	4	1	1.78	0.75	0.85
Productivity Tonne/ha	45	4.5	5	30	40	70	55
Productivity M^3 ethanol/ha	4.07	1.75	2	3	7.1	5.3	4.7

BIOCHEMICAL CONVERSIONS
ethanol production (4)

Fermentation of organic; Ligno-cellulosic and glucidic materials.

☞ Ligno-Cellulosic materials (wood, straw,…)

Fermentescible 'juice'	→	Fermentation	→	Distillation rectification
Destruction of the cristaline structure surrounding the cellulose (mechanical, acid, thermochem., steam explosion)		Enzymatic Hydrolisys		Rectification Dehydratation

THERMOCHEMICAL CONVERSION
synthetic fuels production (1)

Hydrocracking

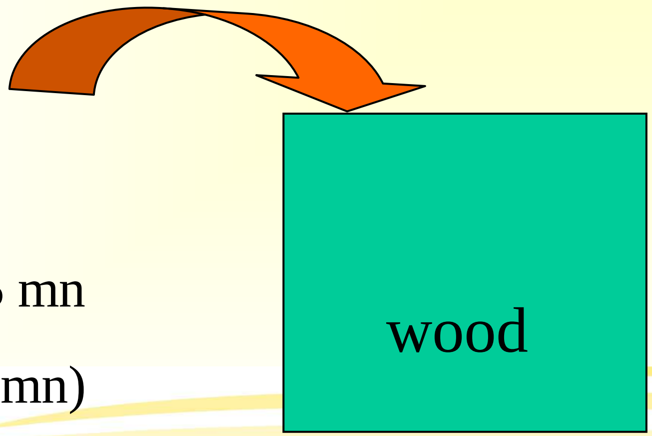
☞ Hydrocracking (wood, straws,…)

300 bars,

450 °C :

(350°C in 15 mn

450°C in 20 mn)



Example:

1 tonne of wood =>

112 kg gas

240 kg light fraction

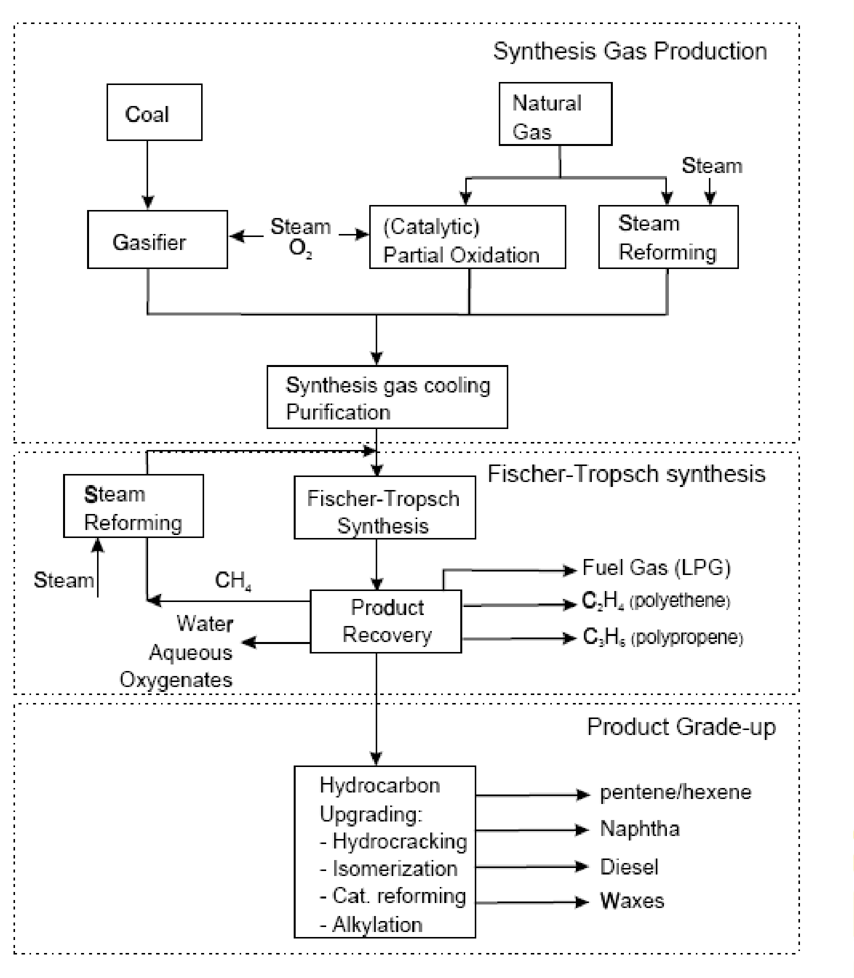
310 kg heavy fraction

355 kg aqueous fraction

THERMOCHEMICAL CONVERSION synthetic fuels production (2)

Gasification

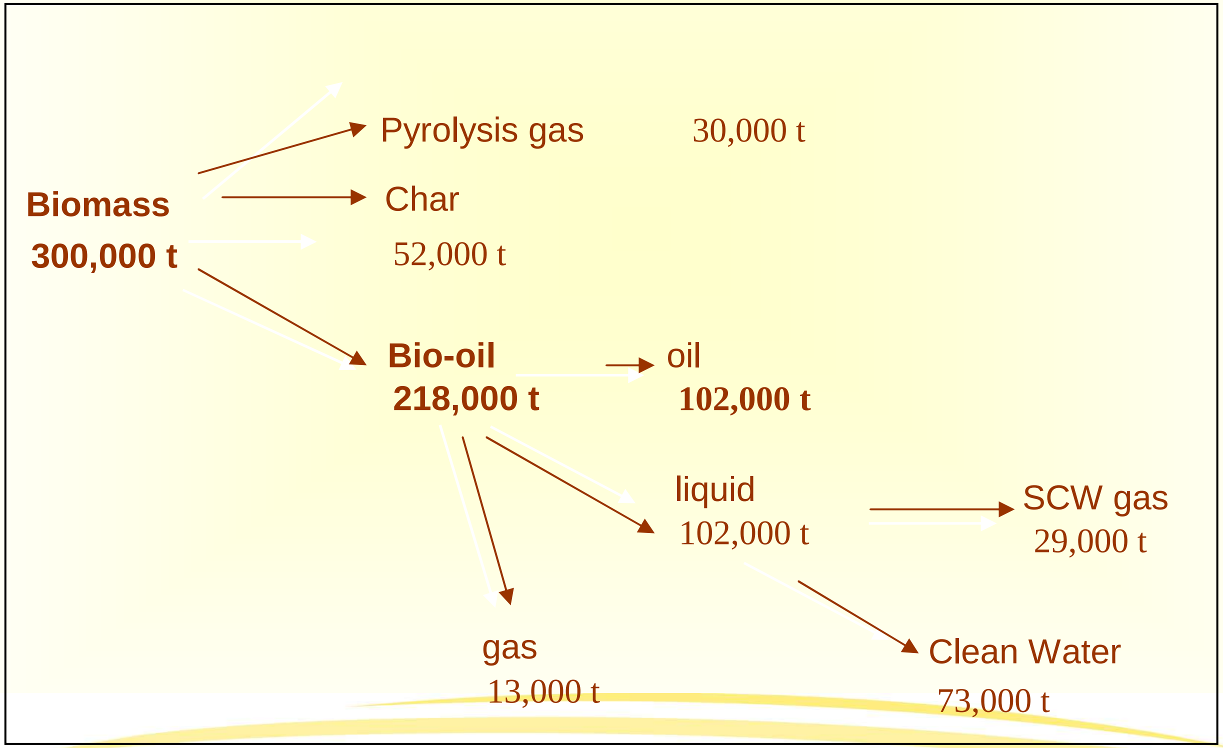
Investigations are towards the substitution of coal by charcoal or raw biomass



At high temperature (350°C), Fisher-Tropsh synthesis produces gasoline and light olefins

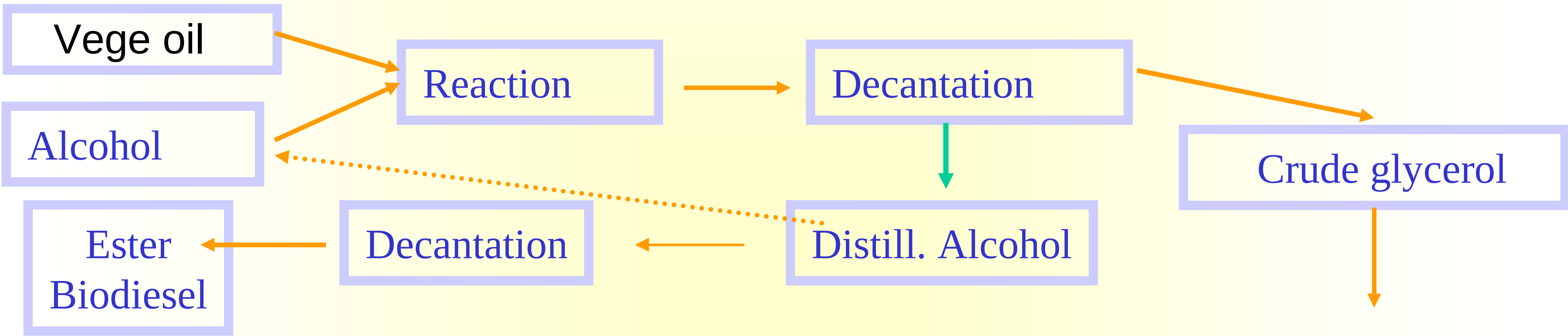
THERMOCHEMICAL CONVERSION
synthetic fuels production (3)

Pyrolysis



ESTERIFICATION OF VEGETABLE OILS

Biodiesel production



1 tonne Veg oil + 0. 1 tonne alcohol + catalyst → 1 tonne Ester + 0. 1 tonne glycerol

ESTERIFICATION:

METHANOL OR ETHANOL ?

Methanol :

- Highly toxic not « renewable » at present
- Low solubility in oil, high solubilization glycerol ⟶ easy decantation

Ethanol :

- Can be « renewable »
- Higher boiling point (78.3 / 64.7 atm pres) but lower heat of vaporization (204 / 270 $cal.g^{-1}$
- Hydratable (appropriate storage), increases soap formation…
- Acts as co solvent to both ester and glycerol ⟶ difficult phase separation

Additional solvent :

- can be expensive and difficult to remove (boiling range of alcohol) ⟶ diesel fuel itself
- May helps phase separation during work out
- But traces left in glycerol are troublesome

➡ Ethanolysis workable (linked to an optimized excess)

Requires careful study, phase diagram, complicated because dependant on the process (neoformed surfactant : soap and monoglycerides)

BIOFUELS FUNDAMENTALS

- **Ethanol as Fuel in Petrol Engines**

ETHANOL FUEL HISTORY

Brasil

Everything started in 1931

ALCOHOL BIOFUEL

- 1975 : first ethanol cars

-In 1994 Brazil had more than 4.6 million alcohol cars;

-When the international oil price was reduced in the late 80s years, the government draw back the subsidy,

Conclusion : in 1999 sales of alcohol based cars represented only 1 %

ALCOHOL BIOFUEL

-Nowadays, all Brazilian gasoline has 25% of alcohol – so, all engine cars are moved by alcohol pure or in blends

- In Brazil spark ignition engines are adapted to :

  * one fuel = gasoline + alcohol
  * “Flex two fuels” = gasoline + alcohol or only alcohol,
  * “Flex three fuels” = gasoline + alcohol or only alcohol or only natural gas (VNG).

1. ALCOHOL BIOFUEL

	Diesel	Gasoline	Bioethanol (95)	Rapeseed oil
Density (kg/dm^3)	0.83	0.75	0.79	0.92
Lower Heating Value (kJ/kg)	43800	44000	26900	39500
Air Fuel Ratio (g air/g fuel)	15.00	14.60	8.9	14.50
Octane number (IOR)	20	98	106	12
Cetane number	50	15	5	37

ALCOHOL BIOFUEL

Constraints ?

Blends with less than 10 %

. stability, content of water
. Volatility (cold starting)
. Corrosion of materials

Blends with more than 30 %

. New engine settings or design
. Corrosion of materials
. Performance: Eff. + 10% power + 15%
. Pollutant: aldehydes
. lubrication

ALCOHOL BIOFUEL

Vulnerabiliy of materials

Vulnerable	**Compatible**
Mg and Zn alloy. Carburator .... **lead :** **Fuel tanks**	**Others metal or alloy**
Polyurethane, PVC, polyamides **polymethacrylates, rubber nitrile** **rubber acrylic**	**Polyethylene** **Silicones** **Polyacetates** **Teflon** **Polyesters**

ALCOHOL BIOFUEL

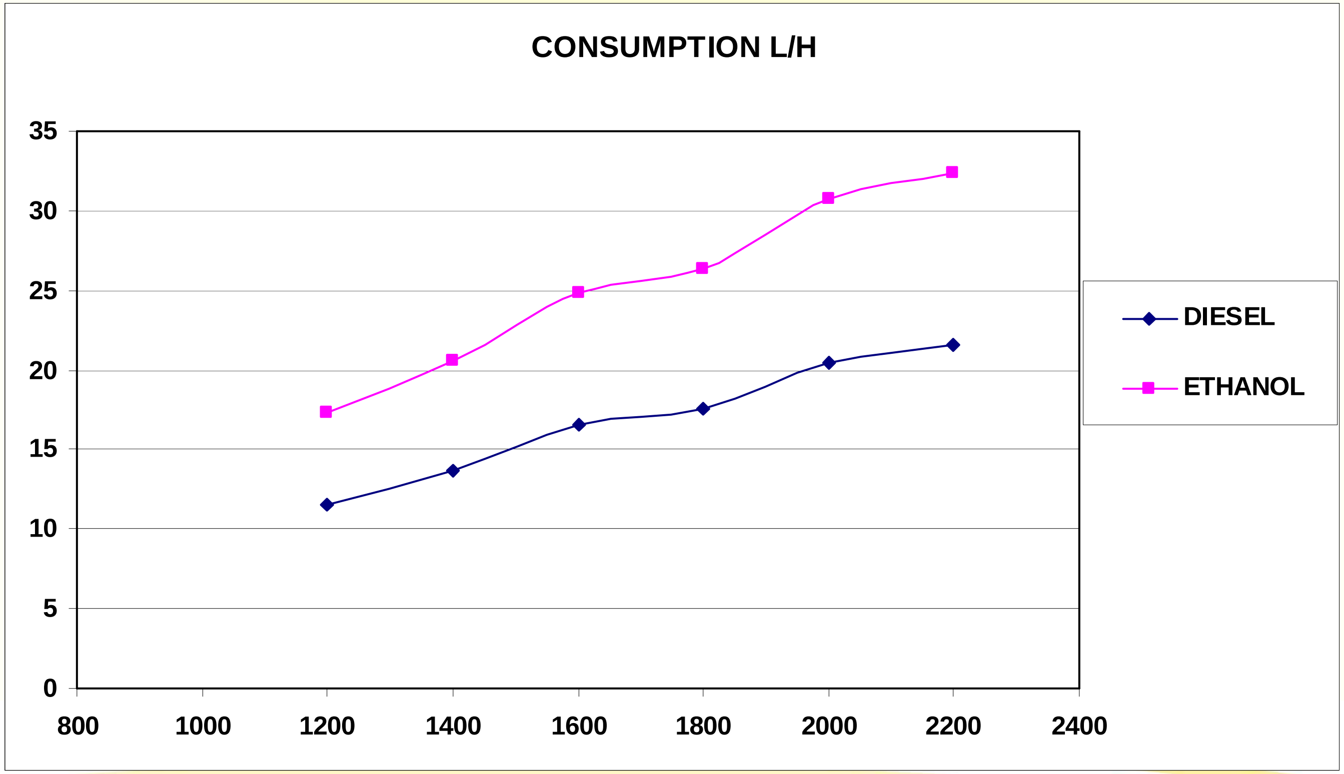
Mauritius & Island of La Réunion : 100 % sugar cane alcohol applied in diesel engines

ALCOHOL BIOFUEL

PERFORMANCE

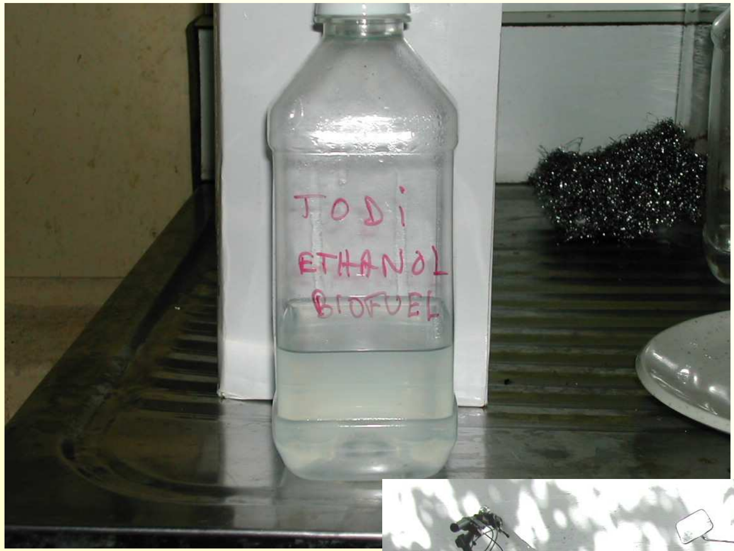
ALCOHOL BIOFUEL

PERFORMANCE



ALCOHOL BIOFUEL

Example of BioEthanol production



Ethanol produced from todi.   TUVALU

BIOFUELS FUNDAMENTALS

- **Vegetable oils as Fuel in Diesel Engines**

HISTORY OF VEGETABLE OILS AS FUEL

SINCE NEOLITHIC PERIOD : 9000 before J.C.

BUT: APARITION OF PETROL LAMPS IN 1853

HISTORY OF VEGETABLE OILS AS FUEL

Rudolf DIESEL (1858 – 1913)

1900 : test of some vegetable oils in his engine

VEGETABLE OILS AS FUEL

- Characteristics close to diesel oil

LCV coconut oil: 41 MJ/kg
LCV Diesel oil: 44 MJ/kg

Density coconut oil: 0.92
Density Diesel oil: 0.83

- History:

  - Mr. Diesel himself in 1900
  - World War II
  - Banned from research in the 50’
  - interest renewed at the end of 70’
  - But: last International Congress in 1982.

VEGETABLE OILS AS FUEL
Why so few applications ?

- higher cost than diesel ☞ case of most renewable

  But new position with > USD 60/barrel

- too different to respect fuel standards

  New standards on the way: Germany, and soon Fiji

- considered as high income agri-products Only for some "niche"

- " Food versus energy" New concept of Sustainable development

- Coconut Oil ! Not to be compared to a cheap, common and stinking product New consideration → USD 60 for 159 liters

VEGETABLE OILS AS FUEL
Two ways =>

• Methyl or Ethyl Esters ☞ any Diesel engine

called "**Biodiesel**"

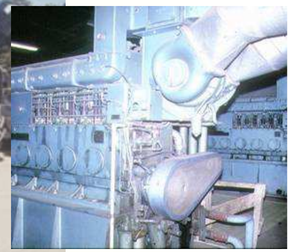
• Natural or " crude" ☞ only in adapted Diesel engines

BUT IT IS POSSIBLE !!!

EXAMPLE OF PURE VEGETABLE OILS USES

DIESEL INJECTION INDIRECTE

DIESEL INJECTION DIRECTE



Principe de la modification

Exemple : FIAT 80 ch.

Tractor Biocombustible Yumz D-65 M, Sunflower or soja

UBPC Victoria 2, Camagüey – CUBA (2003)

IVORY COAST

Genset 320 KVA – crude Palm Oil (2006)

MIXTURES OF COCONUT OIL
in DIRECT INJECTION ENGINES

BUT RUNNING AT LOAD > 50 % => > 200 KVA

Cummins genset , 400 KVA, 10-20 % CNO in DIESEL FUEL

Savai'i EPC Power station, Samoa (2005)

COCONUT OIL IN AN DI ADAPTED DIESEL ENGINE

2004 GENSET. 300KVA

Power Station of ENERCAL (Utility)

CRUDE COCONUT OIL AS FUEL

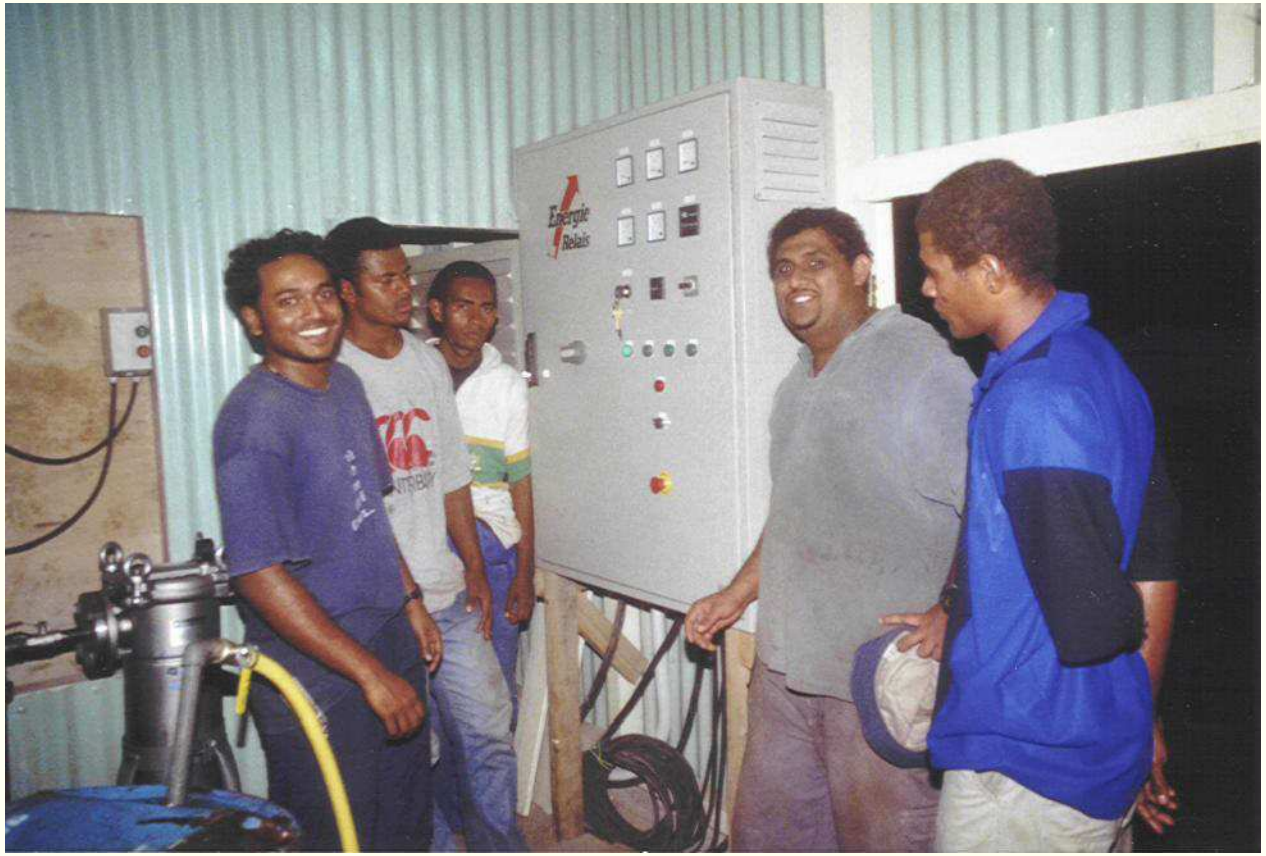
RURAL ELECTRIFICATION:

Fiji: Vanuabalavu 80 KVA* & Welagi 45 KVA

Coconut Oil as fuel (10 nuts = 1 litre equivalent Diesel Fuel)

** First place in the World to produce grid electricity with its own vegetable oil (April 2000).*

COCONUT OIL IN AN IDI ADAPTED DIESEL ENGINE

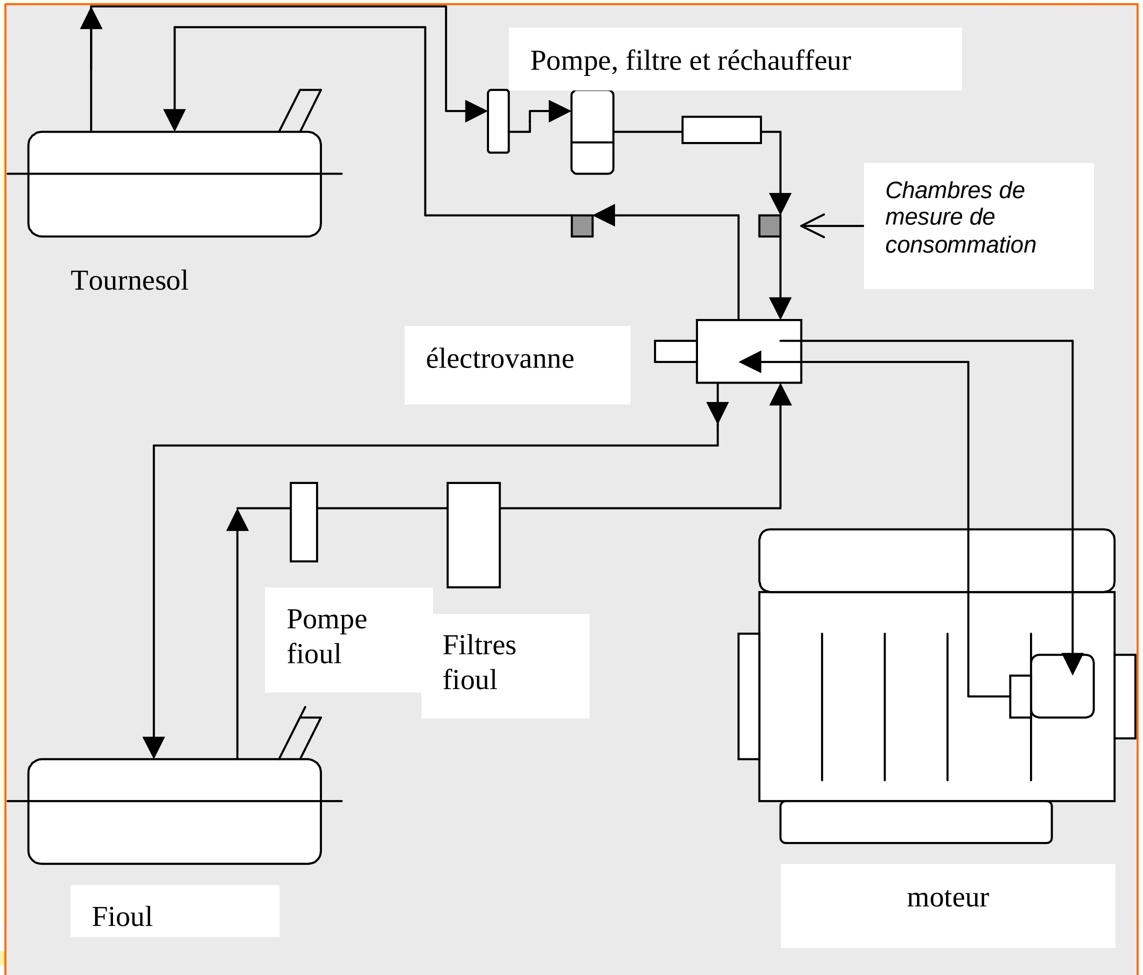


DoE staff at the very starting of Welagi genset with coconut oil (July 2001)

DIESEL DIRECT INJECTION SUNFLOWER OIL

SYSTEM OF DOUBLE CIRCUIT

Renault dci 270 Ch (2006)



CIRCUITS DE CARBURANT DU TM150 BIO

BIOFUELS FUNDAMENTALS

- **BioDiesel in Diesel Engines**

ESTERIFIED VEGETABLE OILS OR BIODIESEL AS FUEL

EXAMPLE OF ESTERIFIED VEGETABLE OIL

ESTERIFIED VEGETABLE OILS OR BIODIESEL AS FUEL

CME Coconut oil Methl Ester			
Diesel	**Parameters**	**CME**	**Benefits**
51	**Cetane number**	70	Better ignition & acceleration
49°C	**Flash point**	106°C	Enhanced safety in storage
0.05 %	**Sulfur content**	0 %	No sulfur emission
0 %	**Oxygen content**	11 %	Clean burning, less smoke (but less energy content)
3-4 cst	**viscosity**	2-3	Good atomization
3800	**Lubricity (gms)**	> 7000	Enhances efficiency of fuel pump & injector unit
mild	**Solvency & detergency**	high	Declogs/restores fuel nozzle spray efficiency
0.05 max	**Water & sediments**	0.0	Durability of injection systems (if respected)
-	**Total glycerine**	0.145	Must not be > 0.24

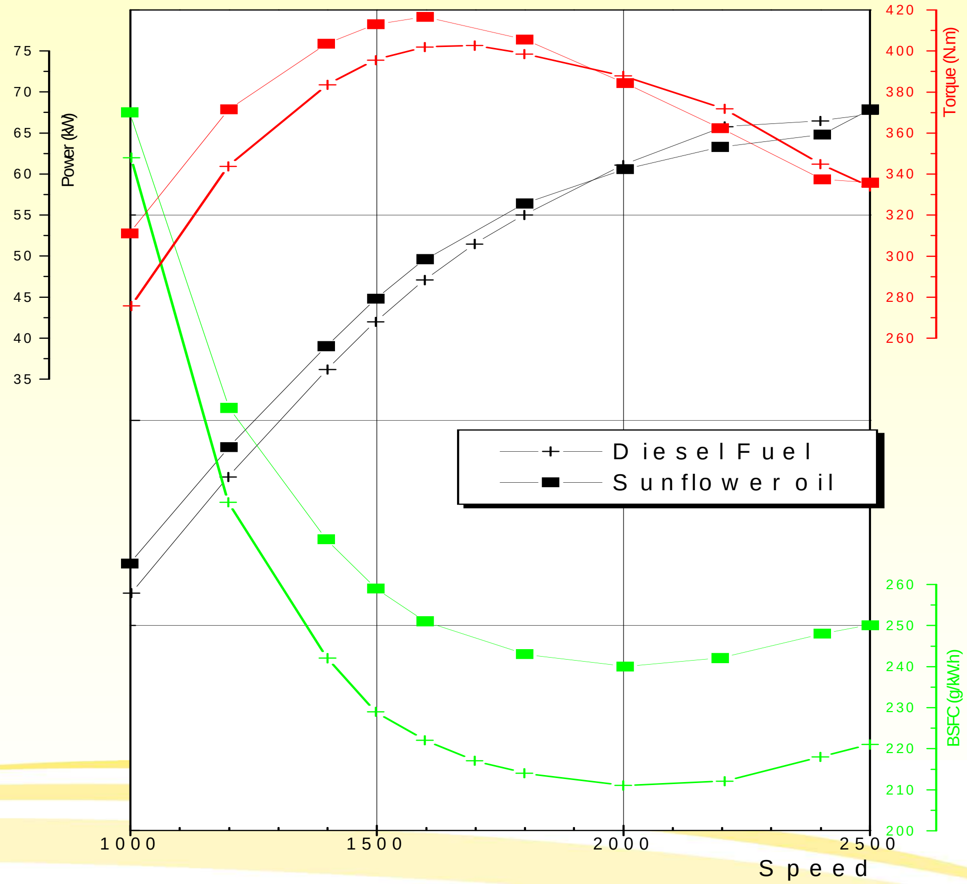
Source: R.S. Diaz, Asia Biofuel Conference, Manila, Dec. 2005.

ESTERIFIED VEGETABLE OILS OR BIODIESEL AS FUEL

PERFORMANCE:

Efficiency: + 3%

Consumption: + 5 %

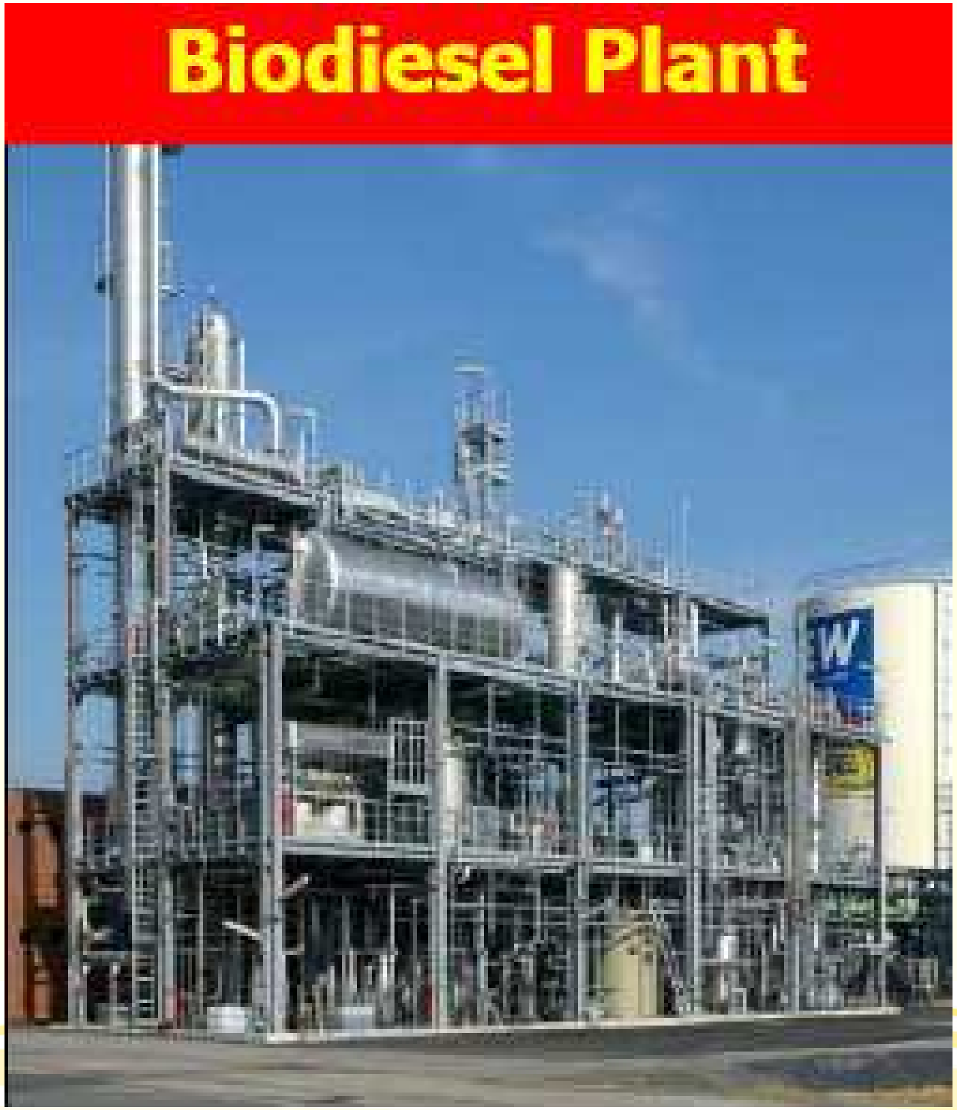


ESTER OF VEGETABLE OIL

50 % Diesel - 50 % Methyl Ester (rapeseed oil)

Reims - France

METHYL ESTER OF VEGETABLE OIL



ESTER OF VEGETABLE OILS

Small scale Unit 40 l./day

(doc. Green Fuels UK)

2 tonnes/day Biodiesel Unit

(Ageratec   Sweden)

Source : Cirad Vaitilingom

ESTER OF VEGETABLE OILS

Example:

Demo of Coconut Oil Methyl Ester processing (doc. Alofa Tuvalu)

Source : Cirad Vaitilingom

DO BIOFUELS CAN REPLACE DIESEL AND PETROL AT THE WORLD LEVEL ?

FUELS - WORLD CONSUMPTION

- World consumption of oil: 80 millions of barrels/day (2/3 for transports)
- 12 720 millions litres or 10 176 millions kg = 10,17 millions of toe/day
- transports = **6.78** millions toe/day, or: 2475 millions toe/year)

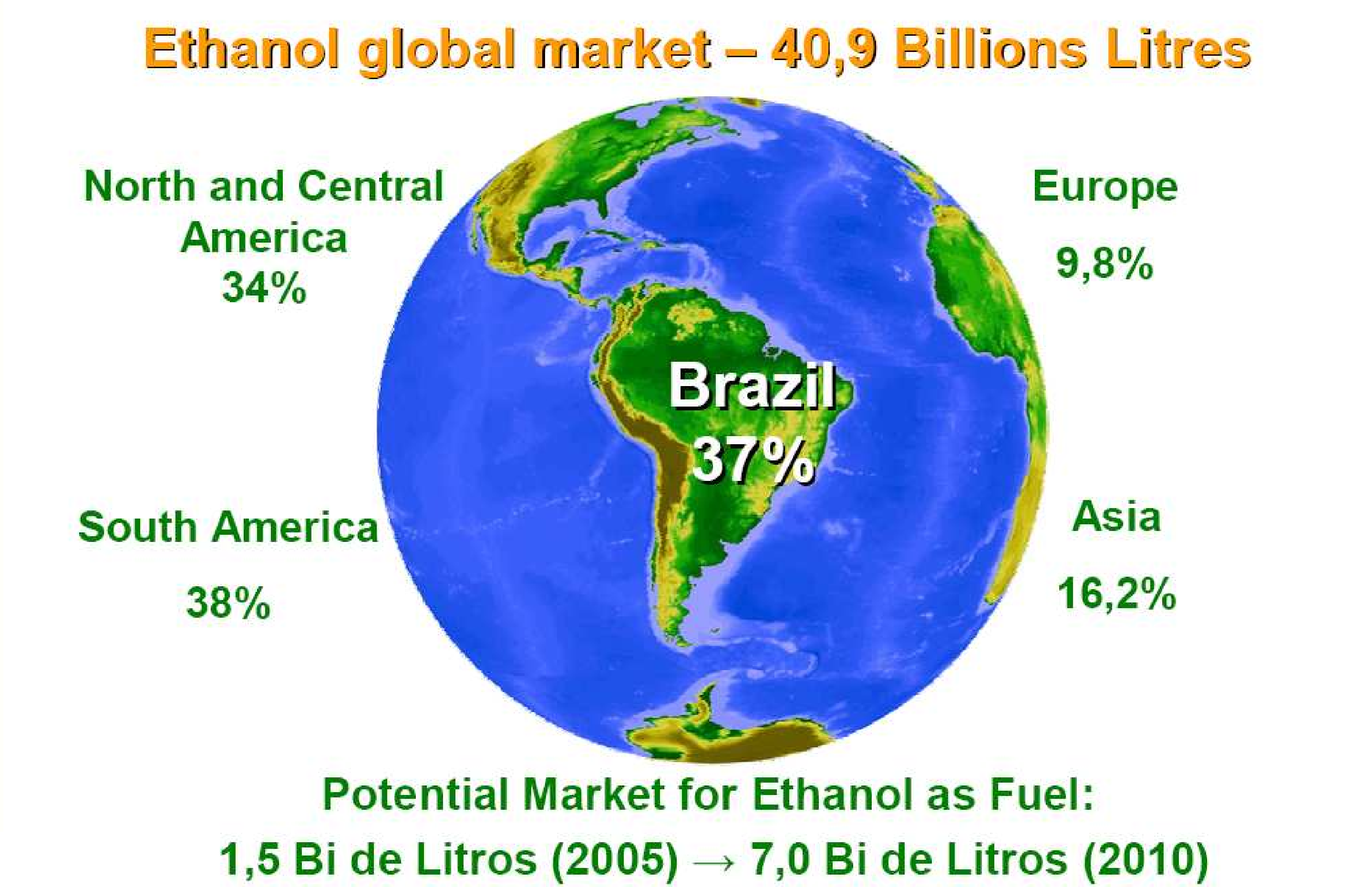
1st GENERATION BIOFUELS

VEGETABLE OILS WORLDWIDE PRODUCTION 2007

Production Millions tonnes	Production (M de tonnes)	2006-2007 (estim.)		2005-2006 (prév.)
Palm	Palme	38,44	30%	35,81
Soya	Soja	36,66	28%	34,94
Rapeseed	Colza	18,47	14%	18,07
Sunflower	Tournesol	11,25	9%	10,95
Cottonseed	Coton	4,94	4%	4,91
Palm kernel	Palmiste	4,46	4%	4,20
Peanut	Arachide	4,31	3%	4,61
Coconut	Coco	3,27	3%	3,28
others	Autres	6,90		6,13
	Total	**128,70**	**100%**	**122,9**

EQUIVALENT TO: 116 millions toe

1st GENERATION BIOFUELS



EQUIVALENT TO: 20 millions toe

1st GENERATION BIOFUELS

- Whole Palm oil production can run world transport for less than 6 days !!! (1 tonne oil = .92 toe)
- World coconut oil production: half a day.
- All vegetable oils can run it during 17 days.
- Brazilian Ethanol can run it 1 day and 9 hours.
- All World Ethanol can run it during 3 days and 18 hours !

We are not at the same level !

But they are well adapted and opportune solutions at local level for welfare and sustainable development.

2nde GENERATION BIOFUELS

	Bio carburants	*l/ha*	*GJ/ha*
1st	Tournesol biodiesel Soja biodiesel Colza biodiesel Blé éthanol Mais éthanol Betterave éthanol Cane à sucre éthanol	1,000 500-700 1,200 2,500 3,100 5,500 5,300-6,500	35.7 17.8- 25.0 42.8 53 65.7 116.6 112.4- 137.8
2nd	FT biodiesel plantation eucalyptus Méthanol plantation eucalyptus DME plantation eucalyptus	13,500-18,000 49,500-66,000 45,000- 60,000	463.1- 617.4 772.2- 1029.6 846.0- 1128.0

Synthetic fuels production

Coal to Liquids : example of SASOL (RSA)

…applicable to biomass ?

Synthetic fuels production

Coal to Liquids : example of SASOL (RSA)

Potential: 25 % of total fossil fuels

Available: 2020 - 2025

Environmental Impact

	Petrol	Diesel	Biodiesel Rapeseed	Biodiesel sunflower	Rapeseed oil pure	Sunflower Oil pure	Coconut Oil	Ethanol sugar cane	Ethanol wheat
Energy balance (Output / Input fossil)	0,879	0,913	3,3	3,44	5,09	5,78	15	7,34	3,57
Green House Gas indicator (g. equiv CO2/kg)	3560	3390	1332	1117	990	747	185	670	505

coconut plantations are assumed to use traditional, non-intensive farming practices with virtually no mechanization or utilization of chemical aids such as fertilizers and pesticides

THANK YOU FOR ATTENTION!

MERCI POUR VOTRE ATTENTION !

MERCI PO

TENTION !

SUBSITUTE FUELS FOR TRANSPORT:

1st GENERATION = 10 % ; 2nd GENERATION = 25 %

65 % TO BE FOUND !!! (Before 2020 ? 2030 ?)